



Full-Plane STWAVE with Bottom Friction: II. Model Overview

By Jane McKee Smith

PURPOSE: The purpose of this System-Wide Water Resources (SWWRP) Technical Note is to describe the full-plane version of the STWAVE wave generation and transformation model (Smith et al. 2001; Smith 2001; Smith and Smith 2002; and Smith and Zundel 2006).

BACKGROUND: STWAVE-FP solves the steady-state conservation of spectral wave action along backward traced wave rays (Smith 2001). The model is used to compute wave transformation (refraction, shoaling, and breaking) and wind-wave generation. The features of the full-plane model include:

- Wave transformation and generation on the full 360-deg plane.
- Option for spatially variable winds and surge.
- Option for spatially constant or spatially variable bottom friction.
- Option for one-dimensional (1-D) wave transformation on lateral boundaries.
- Option for direct input of wave parameters (height, peak period, and mean direction).
- Option for input of plane-beach bathymetry.
- Direction bins no longer restricted to 5 deg.
- X and Y grid cell spacing no longer must be the same.

Wave-current interaction is not yet implemented in the full-plane version of the model.

GOVERNING EQUATIONS: Refraction and shoaling are implemented in STWAVE by applying the conservation of wave action along backward traced wave rays. Rays are traced in a piecewise manner, from the previous grid column or row. The two-dimensional (2-D) wave spectra are set as input along all grid boundaries.

The wave ray is traced back to the previous grid column or row (whichever is encountered first), and the length of the ray segment DR is calculated. Derivatives of depth normal to the wave orthogonal are estimated (based on the orthogonal direction) and substituted into Equation 1 to calculate the wave orthogonal direction at the previous column. The wave orthogonal direction for steady-state conditions is given by (Mei 1989; Jonsson 1990).

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$$C_g \frac{D\alpha}{DR} = - \frac{Ck}{\sinh 2kd} \frac{Dd}{Dn} \quad (1)$$

where C_g is group celerity, D is a derivative, α is wave orthogonal direction, R is a coordinate in the direction of the wave ray, C is wave celerity, k is wave number, d is water depth, and n is a coordinate normal to the wave orthogonal.

The energy is calculated as a weighted average of energy between the two adjacent grid points in the column and the direction bins. The energy density is corrected by a factor that is the ratio of the 5-deg standard angle band width to the width of the back-traced band to account for the different angle increment in the back-traced ray. The shoaled and refracted wave energy is then calculated from the conservation of wave action along a ray.

The governing equation for steady-state conservation of spectral wave action along a wave ray is given by (Jonsson 1990):

$$(C_g)_i \frac{\partial}{\partial x_i} \frac{CC_g \cos(\alpha) E(\omega, \alpha)}{\omega} = \sum \frac{S}{\omega} \quad (2)$$

where

$$\begin{aligned} E &= \text{wave energy density divided by } (\rho_w g), \text{ where } \rho_w \text{ is density of water} \\ S &= \text{energy source and sink terms} \end{aligned}$$

In a strong opposing current (e.g., ebb currents at an entrance), waves may be blocked by the current. Blocking occurs if there is no solution to the dispersion equation. Or, to state it another way, blocking occurs if the relative wave group celerity is smaller than the magnitude of the opposing current, so wave energy cannot propagate against the current. In deep water, blocking occurs for an opposing current with magnitude greater than one-fourth the deepwater wave celerity without current ($0.25 g T_a / (2\pi)$, where T_a is the absolute wave period and g is the acceleration of gravity). If blocking occurs, the wave energy is dissipated through breaking. Lai, Long, and Huang (1989) performed laboratory experiments that showed that wave energy can pass through the linear blocking point through nonlinear energy transfers to lower frequencies (which are not blocked). These nonlinear energy transfers are not included in STWAVE.

SOURCE AND SINK TERMS

Surf-Zone Wave Breaking. The wave-breaking criterion applied in the first version of STWAVE was a function of the ratio of wave height to water depth

$$H_{mo_{\max}} = 0.1L \tanh kd \quad (3)$$

where H_{mo} is the energy-based zero-moment wave height. At a coastal entrance, where waves steepen because of the wave-current interaction, wave breaking is enhanced because of the increased steepening. Smith et al. (1997) performed laboratory measurements of irregular wave

breaking on ebb currents and found that a breaking relationship in the form of the Miche criterion (1951) was simple, robust, and accurate (see also Battjes 1982 and Battjes and Janssen 1978). Equation 3 is applied in STWAVE as a maximum limit on the zero-moment wave height. The energy in the spectrum is reduced at each frequency and direction in proportion to the amount of prebreaking energy in each frequency and direction band. Nonlinear transfers of energy to high frequencies that occur during breaking are not represented in the model. Model grid cells where the wave height is limited by Equation 3 are flagged as actively breaking cells. These breaking regions can be visualized in the Surface Water Modeling System (SMS) (Zundel 2005).

Wind Input. Waves grow through the transfer of momentum from the wind field to the wave field. The flux of energy, F_{in} , into the wave field in STWAVE is given by (Resio 1988)

$$F_{in} = \lambda \frac{\rho_a}{\rho_w} 0.85 C_m \frac{u_*^2}{g} \quad (4)$$

where

- λ = partitioning coefficient that represents the percentage of total atmosphere to water momentum transfer that goes directly into the wave field (0.75)
- ρ_a = density of air
- ρ_w = density of water
- C_m = mean wave celerity
- u_* = friction velocity (equal to the product of the wind speed, U , and the square root of the drag coefficient, $C_D = .0012 + .000025U$)

In deep water, STWAVE provides a total energy growth rate that is consistent with Hasselmann et al. (1973).

The energy gain to the spectrum is calculated by multiplying the energy flux by the equivalent time for the wave to travel across a grid cell

$$\Delta t = \frac{\Delta x}{\beta \bar{C}_g \cos \alpha_m} \quad (5)$$

where

- Δt = equivalent travel time
- Δx = grid spacing
- β = factor equal to 0.9 for wind seas
- \bar{C}_g = average group celerity of the spectrum
- α_m = mean wave direction, relative to the grid

Wave-Wave Interaction and Whitecapping. As energy is fed into the waves from the wind, it is redistributed through nonlinear wave-wave interaction. Energy is transferred from the peak of the spectrum to lower frequencies (decreasing the peak frequency or increasing the peak period) and to high frequencies (where it is dissipated).

In STWAVE, the frequency of the spectral peak is allowed to increase with fetch (or equivalently propagation time across a fetch). The equation for this rate of change of f_p is given by

$$(f_p)_{i+1} = \left[(f_p)_i^{7/3} - \frac{9}{5} \zeta \left(\frac{u_*}{g} \right)^{4/3} \Delta t \right]^{-3/7} \quad (6)$$

where the i and $i+1$ subscripts refer to the grid column indices within STWAVE and ζ is a dimensionless constant (Resio and Perrie 1989). The energy gained by the spectrum is distributed within frequencies on the forward face of the spectrum (frequencies lower than the peak frequency) in a manner that retains the self-similar shape of the spectrum.

Wave energy is dissipated (most notably in an actively growing wave field) through energy transferred to high frequencies and through wave breaking (whitecapping) and turbulent/viscous effects. There is a dynamic balance between energy entering the wave field because of wind input and energy leaving the wave field because of nonlinear fluxes to higher frequencies (Resio 1987; 1988). The energy flux to high frequencies is represented in STWAVE as

$$\Gamma_E = \frac{\varepsilon g^{1/2} E_{tot}^3 k_p^{9/2}}{\tanh^{3/4}(k_p d)} \quad (7)$$

(Resio 1987), where

- Γ_E = energy flux
- ε = coefficient equal to 30
- E_{tot} = total energy in the spectrum divided by $(\rho_w g)$,
- k_p = wave number associated with the peak of the spectrum

The energy loss from the spectrum is calculated by multiplying the energy flux by the equivalent time for the wave to travel across a grid cell (Δt) (Equation 5) with β equal to 1.0 for the swell portion of the spectrum and 0.9 for the sea portion of the spectrum. This dissipation is only applied in the model if wind input is included.

Bottom Friction. STWAVE includes two formulations for bottom friction. The first is the JONSWAP formulation (Hasselmann et al. 1973, Padilla-Hernandez 2001), where the spectral energy loss from bottom friction is formulated as

$$S_{bf} = \frac{-1}{g} c_f \frac{\sigma^2}{\sinh^2 kd} E(f, \alpha) \quad (8)$$

The value of the friction coefficient c_f can be specified as a constant over the domain or specified for each STWAVE grid cell. For the JONSWAP bottom friction formulation, c_f is specified as Γ/g , where the recommended values of Γ are in the range 0.038 to 0.067 m²/s³ (or $c_f = 0.004$ to 0.007) for sand beds based on experiments in the North Sea. Equation 8 has a weak inverse dependence on water depth (related to the increase in bottom wave orbital velocity as the relative depth, kd , decreases).

A Manning formulation is also available in STWAVE (Holthuijsen 2007),

$$S_{bf} = \frac{-1}{g} \left(\frac{gn^2}{d^{1/3}} \right) \frac{\sigma^2}{\sinh^2 kd} E(f, \alpha) u_{rms} \quad (9)$$

where the value of n is specified as input to STWAVE (either spatially constant or variable) and u_{rms} is the root-mean-square bottom velocity. With the Manning formulation, bottom friction dissipation has an additional inverse dependence on water depth. Estimates of Manning coefficients are available in most fluid mechanics reference books (e.g., 0.01 to 0.05 for smooth to rocky/weedy channels). The preferred method of specifying c_f or n is through calibration with field measurements. Bottom friction in STWAVE has been used to represent dissipation over coral reefs in Hawaii and wetlands in southern Louisiana.

Radiation Stress Gradients. Gradients in radiation stress are calculated in STWAVE to provide wave forcing to external circulation models to drive nearshore currents and water level changes (i.e., wave setup and setdown). Wave-driven currents are generally the dominant forcing for sediment transport in the surf zone. Radiation stress tensors are calculated based on linear wave theory:

$$S_{xx} = \rho_w g \iint E(f, \alpha) \left[0.5 \left(1 + \frac{2kd}{\sinh 2kd} \right) (\cos^2 \alpha + 1) - 0.5 \right] df d\alpha \quad (10)$$

$$S_{xy} = \rho_w g \iint \frac{E(f, \alpha)}{2} \left[0.5 \left(1 + \frac{2kd}{\sinh 2kd} \right) \sin 2\alpha \right] df d\alpha \quad (11)$$

$$S_{yy} = \rho_w g \iint E(f, \alpha) \left[0.5 \left(1 + \frac{2kd}{\sinh 2kd} \right) (\sin^2 \alpha + 1) - 0.5 \right] df d\alpha \quad (12)$$

The gradients in radiation stress are calculated as:

$$\tau_x = -\frac{\partial S_{xx}}{\partial x} - \frac{\partial S_{xy}}{\partial y} \quad (13)$$

$$\tau_y = -\frac{\partial S_{xy}}{\partial x} - \frac{\partial S_{yy}}{\partial y} \quad (14)$$

Values of τ_x/ρ_w and τ_y/ρ_w are output from STWAVE for use in circulation modeling.

NUMERICAL DISCRETIZATION: STWAVE is a finite-difference numerical model, formulated on a Cartesian grid. Grid cells are not required to be square in the full-plane version (as they are in the half-plane STWAVE). STWAVE operates in a local coordinate system, with the x-axis and the y-axis forming a right-handed coordinate system. Wave angles are defined in a mathematical sense, measured counterclockwise from the x axis.

UNITS: STWAVE is formulated in metric units. Wave heights, water depth, and tide/surge elevations are in meters, winds are in meters/second, periods are in seconds, and energy densities are in m²/Hz/rad. Wave and wind directions are input and output in degrees, measured clockwise from the grid x-axis, but are converted to radians for model computations. Within SMS, the wave heights can be converted to feet and the directions to a global reference for visualization.

STWAVE-FP INPUT: The primary input file for STWAVE-FP is the model parameter file (default file name options.std). This file controls the model simulation by defining the model parameters and input options. The other input files include bathymetry, input spectra, a friction file, and a simulation file that georeferences the model grid and lists the model input and output file names. Each of the input files is described in the following paragraphs.

Model Parameter File. Figure 1 shows the inputs contained in the model parameter file. The definition of each parameter is listed in Table 1.

```
iplane, iprp, icur, ibreak, irs, nselct, ibnd, iter_set, ifric, isurge, iwind
idep_opt, [ni, nj, dx, dy, i_side, d1, slope]
i_bc1, i_bc2, i_bc3, i_bc4
[nfreq, na, f0, df_const]
[iout(1), jout(1)]
[iout(2), jout(2)]
[iout(3), jout(3)]
[iout(4), jout(4)]
.
.
.
[iout(nselct), jout(nselct)]
nest
[inest(1), jnest(1)]
[inest(2), jnest(2)]
[inest(3), jnest(3)]
[inest(4), jnest(4)]
.
.
.
[inest(nest), jnest(nest)]
idd, u_const, udir_const, dadd
idd, u_const, udir_const, dadd
idd, u_const, udir_const, dadd
```

Figure 1. Model parameter file format (parameters in brackets are optional).

Table 1. Model Parameter Definitions		
Parameter	Definition	Comments
IPLANE	= 1 for full-plane model	Future option for combined full- and half-plane version of STWAVE
IPRP	= 0 for propagation and wind-wave generation = 1 for propagation only	
ICUR	= 0 for no wave-current interaction = 1 for wave-current interaction	Wave-current interaction is not yet available in this version (use ICUR = 0)
IBREAK	= 0 to not write breaking indices = 1 to write 0 for nonbreaking and 1 for breaking in each grid cell = 2 to print dissipation in each grid cell	This option provides output to show where waves are breaking
IRS	= 0 to not calculate wave radiation stresses = 1 to calculate and write wave radiation stresses	Radiation stresses are used as input to a circulation model to force wave-driven currents
NSELECT	= number of optional output points	For each output point, wave height, period, and direction are saved to a file called selhts.out and spectra are saved to the spectral output file
IBND	= 0 for single point input on boundary = 1 linear interpolation of spectra on boundaries = 2 for morphic interpolation on boundaries	
ITER_SET	= number of iterations	Typically 1 to 10
IFRIC	= 0 for no bottom friction = 1 for constant JONSWAP bottom friction over grid = 2 for spatially variable JONSWAP bottom friction = 3 for constant Manning bottom friction over grid = 4 for spatially variable Manning bottom friction	For IFRIC = 1 or 2, input value of cf; for IFRIC = 3 or 4, input Manning coefficient
ISURGE	= 0 for constant depth correction over grid = 1 for spatially variable depth correction over grid	
IWIND	= 0 for constant wind over grid = 1 for spatially variable wind over grid	
IDEP_OPT	= 0 for depth field read in from a file = 1 for plane sloping bottom	
NI	= number of grid cells in the x direction	Required only for IDEP_OPT = 1
NJ	= number of grid cells in the y direction	Required only for IDEP_OPT = 1
DX	= grid spacing (m) in x direction	Required only for IDEP_OPT = 1
DY	= grid spacing (m) in y direction	Required only for IDEP_OPT = 1
ISIDE	= side of grid on which depth D1 is defined	Required only for IDEP_OPT = 1
D1	= water depth (m) on ISIDE	Required only for IDEP_OPT = 1
SLOPE	= constant bed slope applied from ISIDE across the grid	Required only for IDEP_OPT = 1
I_BC1, IBC2, IBC3, IBC4	= 0 - constant spectrum set equal to zero = 1 - constant TMA spectrum with H, T, and dir specified = 2 - constant spectrum read from a .eng file (file code 15) = 3 - 1D transformed spectrum (adjacent boundary must be 0, 1, or 2)	
NFREQ	= number of spectral frequency	Required only for I_BC = 1 or all I_BC = 0
NA	= number of angle bands (defines angular resolution)	Required only for I_BC = 1 or all I_BC = 0
F0	= lowest frequency (Hz)	Required only for I_BC = 1 or all I_BC = 0
DF_CONST	= constant frequency increment	Required only for I_BC = 1 or all I_BC = 0
(Continued)		

Table 1 (Concluded)		
Parameter	Definition	Comments
IOUT(NSELECT), JOUT(NSELECT)	= i and j locations for special output points (to save spectra)	
NEST	= number of points to save spectra for nesting	
INEST(NEST), JNEST(NEST)	= i and j locations to save spectra to nest to another grid	
IDD	= time identifier for each model run	
U_CONST	= spatially constant wind speed (m/sec)	
UDIR_CONST	= spatially constant wind direction (degrees relative to STWAVE axis)	
DADD	= spatially constant water level adjustment (m)	

Depth File. The depth file (default file name dep.in) is the same as the half-plane depth file, with the addition of specifying dy in the first line of the file. The orientation of the grid is arbitrary. The first line of the file is ni, nj, dx, and dy (number of x and y grid cells, followed by the x and y grid spacing). Everything is read in free format. The depths are read in the following format:

```
j = nj, 1, -1
      read(10,*) (dep(j,i), i = 1, ni)
enddo
```

Input Spectra File. The input spectra (default file name spec.in) can be specified on any boundaries and at single or multiple points on a boundary. For a single spectral input on a boundary, the spectrum is read in the following format:

```
read (8, *) idd
read (8, *) ( (e_bc(k,l,i_side), l=1,na), k=1,nfreq)
```

If the boundary is nested with multiple spectra specified at the boundary, then the x and y location of the points are also required (in the same coordinate system that the origin and orientation are specified in the first line of the .sim file).

Input Friction File. The friction file (default file name friction.dat) is required only if IFRIC>0. For IFRIC = 1 or 3 (spatially constant friction), the file contains a single value of the friction coefficient. For IFRIC = 2 or 4 (spatially variable friction), the file has the same format as the input depth file. For the JONSWAP friction formulation, the friction coefficient is specified as Γ/g (IFRIC = 1 or 2) and for the Manning friction formulations, the coefficient is specified as a Manning n (IFRIC = 3 or 4).

Input Surge File. The surge file (default file name surge.in) is required only if ISURGE = 1 (spatially variable surge). For ISURGE = 0 (spatially constant tide or surge), the water level addition is provided in the model parameter file (DADD). The water level is specified in meter relative to the datum of the depth file (positive values increase the water depth and negative

values decrease the water depth). The file has the same format as the input depth file. The surge must be specified for each simulation time/case.

Input Wind File. The wind file (default file name wind.in) is required only if IWIND = 1 (spatially variable wind). For IWIND = 0 (spatially constant wind), the wind speed and direction are provided in the model parameter file (U_CONST and UDIR_CONST). The first line of the file is ni, nj, dx, and dy (number of x and y grid cells, followed by the x and y grid spacing). The fields of wind speed (m/sec) and wind direction (deg, relative to the grid x-axis) are read in the following format:

```
read (20,*)idd
do j = nj, 1, -1
  read (20,*) (u(j,i), i=1,ni)
enddo
do j = nj, 1, -1
  read (20,*) (udir(j,i), i=1,ni)
enddo
```

The wind must be specified for each simulation time/case.

Simulation File. The simulation file is a listing of all the input file names. If default file names are not used, the simulation file is required. The first line of the simulation file specifies the model to be applied (STWAVE_FP for full-plane model or STWAVE for half-plane model), the origin of the grid (for example, $x = 1086240.0$ and $y = 210460.0$ in Figure 2), and the grid orientation (x-axis is 270 deg from east in Figure 2). This first line of the simulation file is not used by STWAVE, but required for visualization in SMS. Each input and output file is identified by a key word, which is given in parentheses in the following sentences. The input files are the depth file (DEP), the model parameter file (OPTS), the input spectra file (SPEC), the friction file (FRIC), the surge field file (SURGE), and the wind field file (WIND). The output files are the wave field (WAVE), the output spectra (OBSE), the output spectra for nesting (NEST), the breaking indices (BREAK), and the radiation stresses (RADS). Three additional files summarize input wave conditions generated within SMS: GSPEC, SPGEN, and CASES. The GSPEC file stores spectra generated within SMS, the SPGEN file has the parameters used to generate the spectra, and the CASES file has the wind speed, direction, tide, and boundary conditions for each case specified in SMS. These three SMS files are not required to run STWAVE (the information is stored in the STWAVE OPTS and SPEC files), but the files are useful for documenting the boundary conditions.

```

STWAVE_FP 1086240.0000 210460.0000 270.0000
DEP test.dep
OPTS test.std
SPEC test.eng
WAVE test.wav
OBSE test.obs
NEST test.nst
BREAK test.brk
GSPEC test.wavspec
SPGEN test.txt
RADS test.rad
CASES test.stc
FRIC test.fric
SURGE test.surge
WIND test.wind

```

Figure 2. Sample simulation file.

STWAVE-FP OUTPUT: The primary output file for STWAVE-FP is the wave field (height, period, and direction at all grid cells for all cases, WAVE file). Additional optional output files are wave spectra at selected locations (OBSE file), nesting spectra (NEST), indices indicating whether waves are breaking (BREAK), and radiation stress gradients (RADS). Each of the output files is described in the following paragraphs.

Wave Field File. The wave field file (default file name wavfld) is the same as the half-plane wave field file, with the addition of specifying dy in the first line of the file. The orientation of the grid is arbitrary. The first line of the file is ni, nj, dx, and dy (number of x and y cells, followed by the x and y grid spacing). The following lines are grouped by the time/case identifier (IDD, followed by all the wave heights (m), peak wave periods (sec), and mean wave direction (deg, clockwise from the x-axis). The wave fields are written in the following format:

```

100      Write(13,*)ni, nj, dx, dy
          do ica = 1, ncase
              write (13,*) ica
              do j = nj, 1, -1
                  write (13,100) (H(j,i), i = 1, ni)
100          format(20f6.2)
              enddo
              do j = nj, 1, -1
                  write (13,101) (Tp(j,i), i = 1, ni)
              enddo
              do j = nj, 1, -1
101          write (13,101) (angle(j,i), i = 1, ni)
              format (20f6.1)
              enddo
          enddo

```

Output Spectra File. The output spectra file (default file name spec.out) is the same as the half-plane model. The spectra are grouped by time/case identifier (IDD) and i and j location. The units of energy density are $\text{m}^2/\text{Hz}/\text{rad}$. The spectra are written in the following format:

```

      do nn = 1, nselct
!   write to spectral output file
          write (14, 9003) idd, iout(nn), jout(nn), nn
          do k = 1, nfreq
              write (14, 9004) (e(k, l, jout(nn), iout(nn)), l = 1, na)
          enddo
      enddo
9004   format (72f8.3)

```

When spectral output points are specified, the wave heights, periods, and directions for those output points are written to a file named selhts.out. The format of this file is:

```

          write (12, 9005) idd, iout(nn), jout(nn), H(jout(nn), iout(nn)), Tp(jout(nn), iout(nn)), &
              angle(jout(nn), iout(nn))
9005   format(3i10,3f10.2,i10)

```

The output nesting file contains spectra in the same format as the output spectra file, but the header line also contains the x and y coordinates of the output points.

Output Breaking File. The output breaking file (default file name break) indicates where waves are breaking with a “1” and nonbreaking with a “0”. This information is used in some sediment transport calculations and may be of interest for safety issues. The breaking file is written in the following format with a file header of nx, ny, dx, and dy:

```

          write (22, 9003) idd
          do j = nj, 1, -1
              write (22, *) (ibr(j, i), i = 1, ni)
          enddo
9003   format (i10, 3i5)

```

Output Radiation Stress Gradient File. The output radiation stress gradient file (default file name radstress) contains the x and y gradients in radiation stress. These gradients are used to calculate wave setup and wave-driven currents in circulation models. The radiation stress gradient file is written in the following format with a file header of nx, ny, dx, and dy:

```

          write (18, 9003) idd
          do j = nj, 1, -1
              write (18, *) (wxrs(j, i), wyrs(j, i), i = 1, ni)
          enddo
9003   format (i10, 3i5)

```

SAMPLE RESULTS: The full-plane version of STWAVE has been applied to studies of Hurricane Katrina in Lake Pontchartrain, Louisiana, under the Interagency Performance Evaluation Task Force (IPET 2006). The domain size for Lake Pontchartrain was 41.6 by 67.4 km with a resolution of 200 m. STWAVE and ADCIRC were loosely coupled by passing storm surge fields from ADCIRC to STWAVE and passing radiation stress fields (to calculate wave setup) from STWAVE to ADCIRC. The input for each grid includes the bathymetry, Manning n

values (generated from land use maps), surge fields (interpolated from ADCIRC), and wind fields (interpolated from the ADCIRC wind fields, which apply land effects to the wind fields generated by Ocean Weather, Inc.). The wind and surge fields applied in STWAVE were spatially and temporally variable. STWAVE was run at 30-min intervals from 00:30 UTC on 28 August 2005 to 00:00 UTC on 30 August 2005 (Katrina's landfall was on 29 August 2005).

The peak wave conditions on the south shore of Lake Pontchartrain occur at approximately 13:30-14:30 UTC on 29 August 2005. Figure 3 shows wave height for each grid cell at approximately the peak of the storm (14:30 UTC, 29 August 2005). Areas contoured in dark blue with no vectors (zero wave height) are land. Figure 4 shows the maximum wave height for each grid cell within the domain for the entire simulation period. The maximum wave heights range from 2.4 to 2.7 m on the New Orleans lakefront (bottom of the figure) and the associated peak periods are 7-8 sec. These are approximately the design conditions for the lakefront levees (which performed well during the storm). Figures 3 and 4 were generated using SMS (Smith and Zundel 2006).

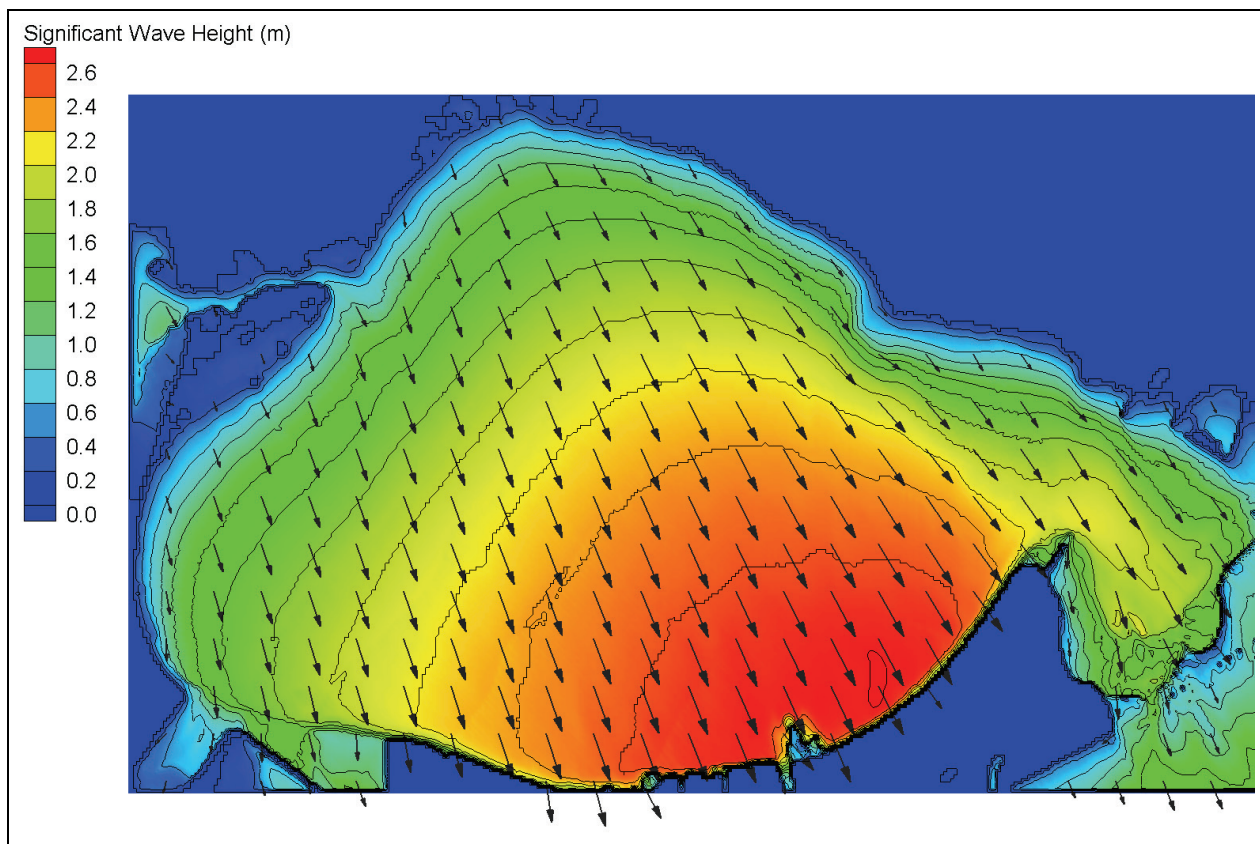


Figure 3. Lake Pontchartrain modeled wave height and direction for 14:30 UTC on 29 August 2005 (wave heights in meters).

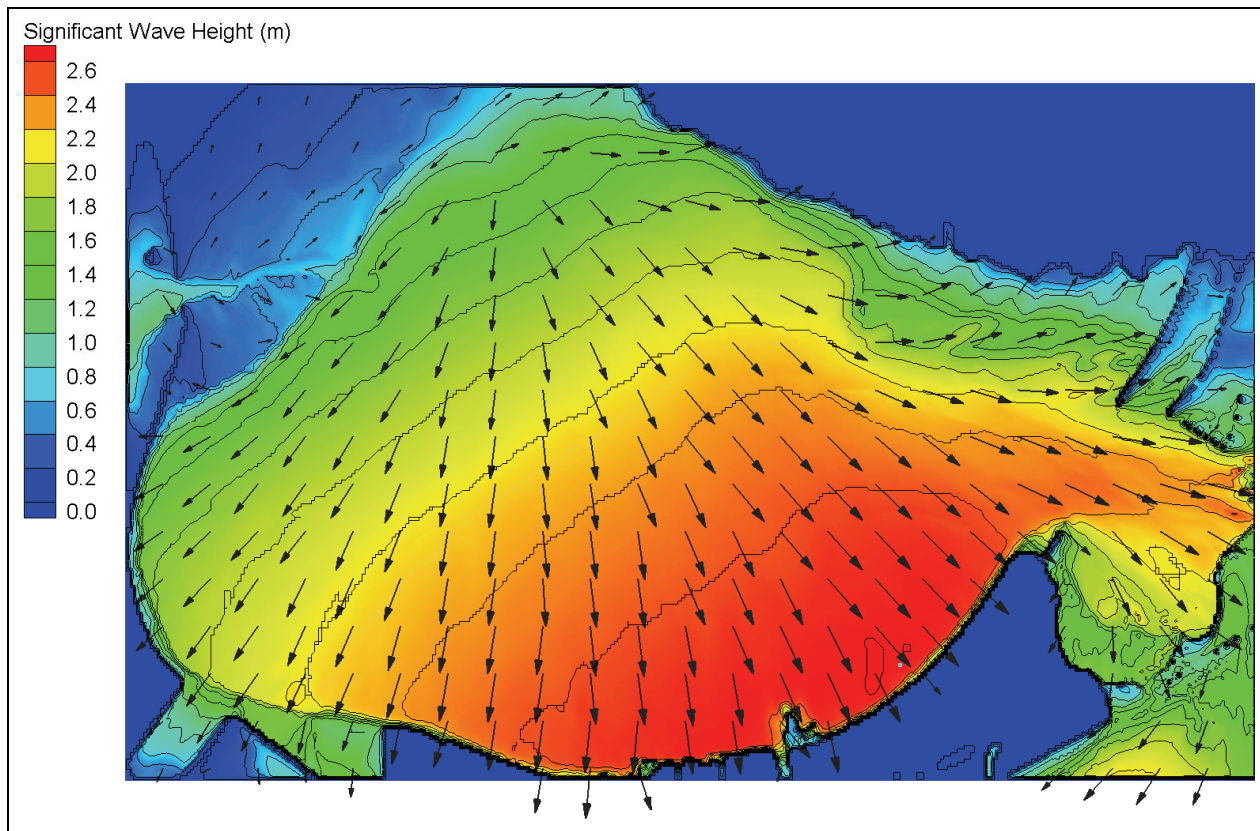


Figure 4. Lake Pontchartrain maximum modeled significant wave height and corresponding mean direction for 00:30 UTC on 28 August to 00:00 UTC on 30 August 2005 (wave heights in meters).

SUMMARY: This SWWRP technical note describes the formulation and application of the full-plane version of STWAVE. The STWAVE-FP includes wave generation and transformation in all directions, bottom friction, and spatially variable winds and surge. An example application to Lake Pontchartrain, Louisiana is also provided.

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Smith, J. M. 2007. *Full-plane STWAVE: II. Model overview*. ERDC TN-SWWRP-07-5. Vicksburg, MS: U.S. Army Engineer Research and Development Center.
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